^{6}Li Surface Area Deterioration

Vivek Jeevan

There is concern that ^{6}Li scintillators we are using to count neutrons might be giving us false results. We have so far not taken into account the possibility of deterioration of detection surface area. After analyzing recently taken data with our scintillators, and calculating ratios of their neutron counts as a function of their sizes, I conclude that deterioration is *not* a factor in our experiments.

Theory of Deterioration

We have two cylindrical ^{6}Li scintillators, both with circular detection areas. One has a 4.05mm diameter [1, p.71], the other 10.12mm [1, p.210]. It is thought that, during the creation process, when the detectors were placed in water, their outer edges may have been chemically damaged. Deteriorated outer rings lost the ability to detect neutrons, thereby reducing the effective radius of detector surface area.

In the abscence of surface area deterioration, if both the 4.05mm and 10.12mm detectors are placed in identical neutron fluxes, the ratios of their neutron counts will be 16.4 : 102.4, or roughly 0.16 (surface area $= \pi \times r^2$). In theory, deterioration would affect both detectors equally – both of their radii will be decreased by the same amount. Therefore, as deterioration *increases*, the ratio of their neutron counts *decreases*. This allows a means to positively identify deterioration, by finding a decrease from the 16.4 : 102.4 ratio when both detectors are placed in an identical neutron flux.

The Data

On 11/23/01, data were taken for this specific problem [1, p. 200]. The 4mm ^{6}Li scintillator, mounted on a phototube, was placed at the center of a neutron beam. The tune gate was set at a count rate of 1.7 kHz, and the T.O.F. gate at 35.48 - 40.44ms. Data were taken of the number of neutrons detected at different thresholds. The 4mm scintillator was then replaced by the 10mm scintillator, and the experiment repeated.

At the energy of the neutrons involved, both scintillators have an efficiency of unity. Therefore, their thicknesses are unimportant.

Theory Of Data Plots

We are only interested in *neutron* counts. Background events can easily trigger false counts. In order to determine background hits from neutron hits, the same measurements of counts vs. threshold were repeated when the the neutron beam was shut *off*. The resulting counts quantified the number of background events. The true neutron count is obtained by subtracting these background counts from the counts taken with the beam on.

The plot of "neutrons vs. threshold" has certain characteristic features. At very low thresholds, noise in the system easily triggers false hits, causing the count rate to be correspondingly high. As the threshold rises, this noise gets filtered, and the graph exhibits a drop in counts. After all noise is filtered, the graph levels out, looking similar to a plateau. The counts on the "plateau" can be completely attributed to neutrons. After a certain threshold, neutrons will no longer deposit enough energy to trigger the discriminator. Past this cutoff threshold, the count rate plummets, and hovers around zero.

Fitting the "plateau," as a method of determining neutron counts

Flux of neutrons in the beam is constant. So theoretically, between threshold limits where only neutrons are being counted (along the "plateau"), the graph should be a flat, horizontal line. To determine the number of neutrons counted, simply check where this line intercepts the y-axis (# of counts). Experimentally, the "plateau" comes *close* to a straight line. Slight differences in neutron energies give the "plateau" a small slope. A good approximation, then, of total neutron counts, can be determined by fitting the "plateau" to a line, and determining the y-intercept of the fit.

A further note about background noise

Tests were done [1, p. 201] that determined that the PMT was "activated," and was itself radiating off photons that it then detected as hits. While the neutron beam was off, the phototube was removed from the scintillators, covered with foil and tape, and then measured for neutron counts. At a threshold of 50.1mV, 147 hits were still counted. A new phototube was then brought in, also unattached to a scintillator and covered with foil and tape. This new phototube produced zero counts.

During this analysis, these false hits were taken into account when total background counts were measured.

Plots

I used the analysis program, PAW, to analyze the data. I took the following steps:

- plotted the initial data of neutron counts vs. threshold
- plotted the background counts
- subtracted the background from the data (plotted in Figures 1a and 2a)
- fit the resulting "plateau" (shown in Figures 1b and 2b)

Results

There were too few key data points for the 4mm scintillator to resolve a plateau. With the computer generated fit, I estimate the neutron count at 17,000 $\pm$370 counts, with the error due to statistics. As a rough estimate for the fit, I used the first three data points, although no method can produce good certainty here. The 3rd data point seems like the lowest possible representation of the plateau or it's wherabouts, so I consider that value as a lower limit. This tacks on an additional systematic error of $\pm$2,800 counts. Adding both the statistical and systematic errors in quadrature, gives a total value of 17,000 $\pm$2,800 neutron counts for the 4mm scintillator.

The data for the 10mm scintillator have a nice plateau, so the neutron count can be easily extrapolated, with negligible systematic error. Its neutron count was 91,600 $\pm$750 counts, with the error due to statistics.

Conclusion

The ratio of neutron counts of our 4mm and 10mm scintillator is: 0.185 ± 0.07. This is *higher* than the theoretical ratio if there were no deterioration at all. Deterioration should result in a *lower* ratio. (If these results were interpreted extremely literally, they would indicate that the active surface areas are actually growing.) Therefore, I find no evidence of active surface area deterioration.

Errors

Error bars for the data are written into the PAW program, and accounted for. This entire analysis assumes that deterioration reduces both radii by the same amount – if one radius deteriorated more than the other, none of the above reasoning can apply.

Deadtime errors are not a significant factor. The rate of hits was very low compared to the 1 microsecond deadtime of the discriminator.

References

[1] NPDGamma logbook II

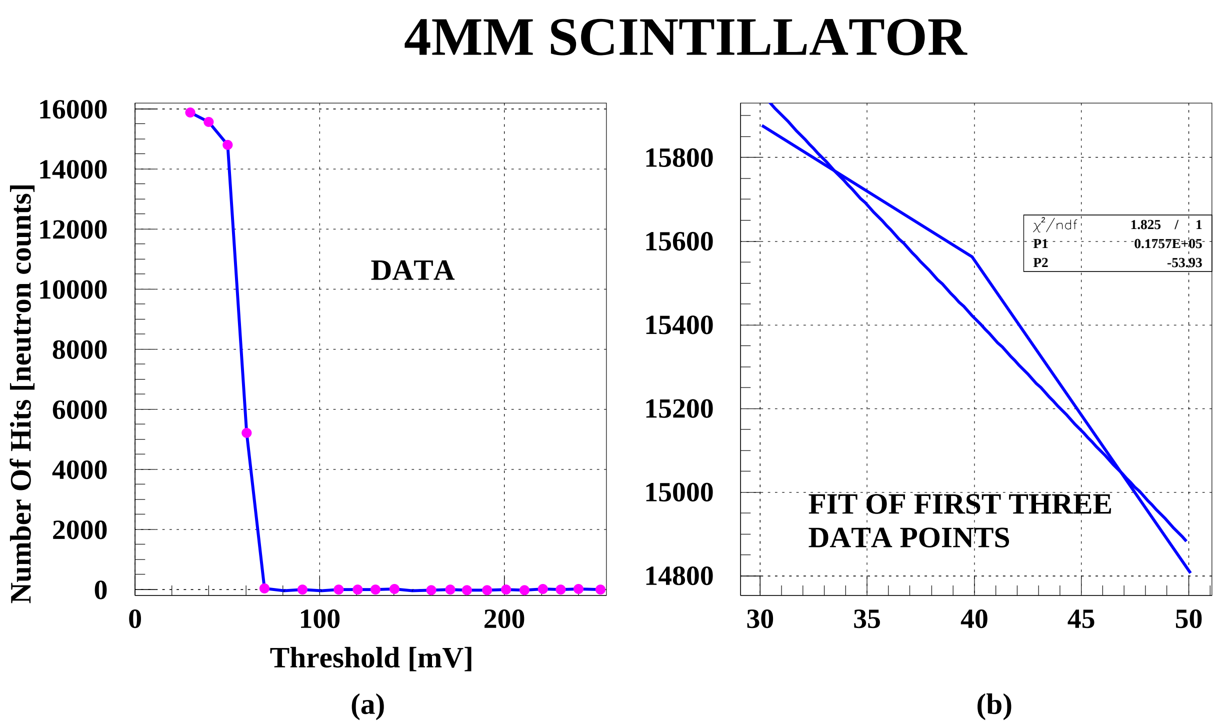

Figure 1: **(a) Data taken when 4mm ^{6}Li scintillator was mounted on a phototube, and placed in a neutron beam. The plot shown is corrected for background noise. (b) Close-up of first three data points. A computer generated fit (the straight line) of these 3 points is superimposed.**

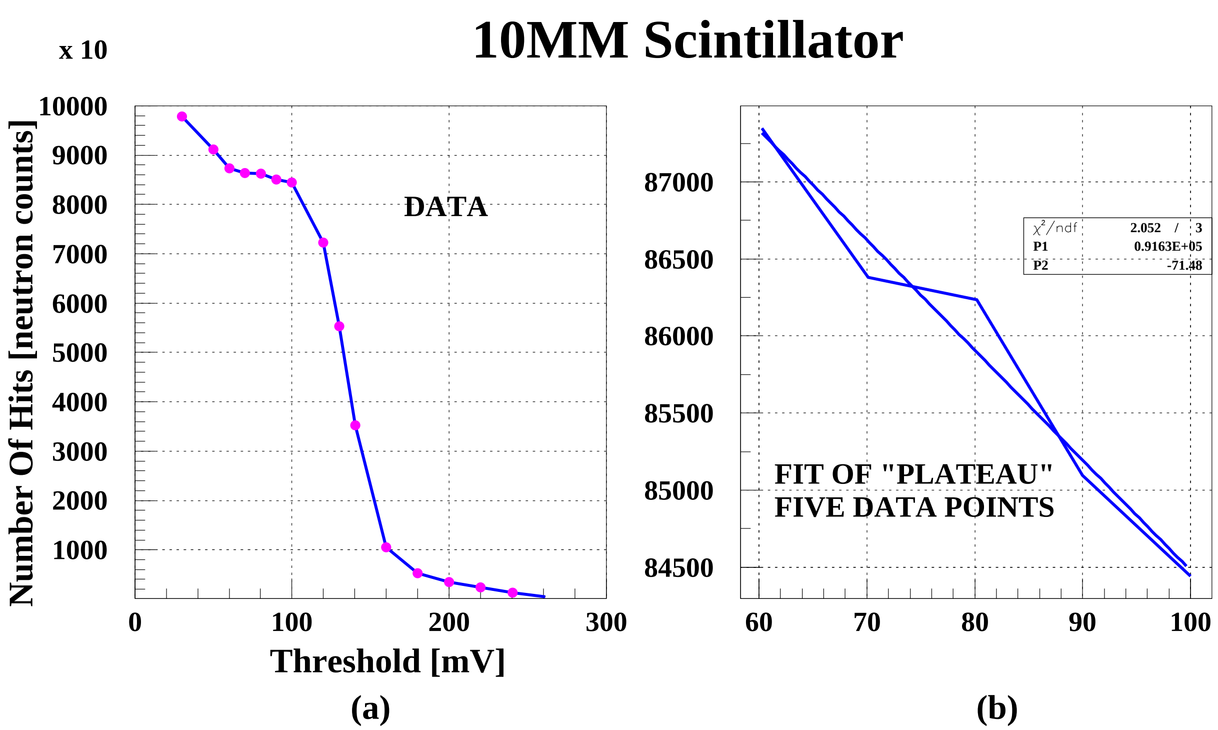

Figure 2: **(a) Data taken when 10mm ^{6}Li scintillator was mounted on a phototube, and placed in a neutron beam. The plot shown is corrected for background noise. (b) Close-up of the five relatively horizontal data points, comprising the characteristic "plateau." A computer generated fit (the straight line) of the "plateau" is superimposed.**